Numerical taxonomy of south Indian *Piper* L. (Piperaceae) I. Cluster analysis[1]

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Abstract

Seventeen Operational Taxonomic Units (OTUs) comprising eleven South Indian species of *Piper* were subjected to a cluster analysis study based on 30 characters. Clustering of characters led to the recognition of six character groupings. The clustering of taxa resulted in the following species groupings: (1) *P. attenuatum, P. argyrophyllum* (2) *P. galeatum, P. trichostachyon* end *P. schmidtii* (3) *P. nigrum, P. nigrum* var. *hirtellosum*, and *P. wightii* (4) *P. hymenophyllum* (5) *P. mullesua*, and *P. silentvalleyensis* (6) *P. longum*. In general, the study supported the existing classificatory scheme of South Indian taxa of *Piper. P. mullesua, p. silentvalleyensis* and *P. longum* were found to be very distinct from the rest of the species and this calls for a revised infrageneric classification of the South Indian taxa of *Piper*.

INTRODUCTION

The genus *Piper* L. (Piperaceae) is, perhaps, the largest genus of flowering plants devoid of a natural classification (Bornstein, 1989). It is taxonomically a very difficult genus because of the large number of species and infraspecific taxa, minute, closely packed, achlamydous flowers brone on spikate inflorescences and variable morphological characters. According to Howard (1973), the family is one of the worst messes in plant taxonomy.

Piper is distributed mainly in the Central and Northern South America in the New World and in India, Malaysia, Indonesia and Sri Lanka in the Old World. In India, the genus has a disjunct distribution, concentrated mainly in the eastern Himalayas in the north and on the Western Ghats in the south.

Western Ghats is an important area of distribution of the genus, as it is the centre of origin of the Black Pepper, *Piper nigrum* L. It is rich in species diversity as well as infraspecific variation. But, saving the floristic account given by Gamble (1925) and the additions made by Ravindran *et al.*, (1987), the much-needed revisionary work on South Indian *Piper* is still wanting.

With this end in view, the N. R. C. S., Calicut has, over the years, made extensive explorations and field studies on the genus on the Western Ghats and has assembled a rich collection of germplasm with special emphasis on south Indian species. This paper deals with a numerical taxonomic study of the south Indian elements using cluster analysis technique

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which forms part of a larger biosystematic study.

MATERIALS AND METHODS

The present study utlised 17 operational taxonomic units (OTUs) comprising of 11 south Indian species (Table 1). Two species (*P. barberi* Gamble and *P. hapnium* Ham.) could not be included in the study because sufficient samples of these endangered species were not available.

OTU No.	Species (OTU)		
1.	Piper attenuatum		
2.	P. argyrophyllum		
3.	P. galeatum		
4.	P. hymenophyllum		
5.	P. longum		
6.	P. mullesua		
7.	P. schmidtii		
8.	P. silentvalleyensis		
9.	P. trichostachyon		
10.	P. wightii		
11.	P. nigrum	(1)	Acc. 2077
12.	-do-	(2)	Acc. 2071
13.	-do-	(3)	Acc. 2009
14.	-do-	(4)	Acc. 2059
15.	-do-	(5)	Acc. 2060
16.	-do-	(6)	Acc. 2015
17.	-do-	(7)	Acc. 2062

The characters and character - states employed in the analysis are given in (Table 2). Observations on 30 characters were recorded using both live as well as herbarium specimens. One hundred observations were recorded in each case, except in *P. silentvalleyensis* in which only very limited quantity of meterial was available. In this case, spike characters were recorded from 25 samples while other morphological characters were recorded from fifty samples. In all cases,

only the mean values were used in the final analysis.

Two different cluster analysis techniques were used : the 'average linkage' for grouping the characters and 'centroid linkage' for grouping the taxa. For the average linkage analysis, the Unweighted Pair Group Method using Arithmatic Averages (UPGMA) was used (Hartigan, 1981) while for centroid linkage, the Unweighted Pair Group Centroid Method (UPGCM) was made use of (Engleman, 1981).

The computer analysis was carried out at the Computer Centre of Carnegie-Mellon University, Pittsburgh, USA, using the BMDP-81 Programme Package developed by the Department of Biomathematics, University of California, Los Angeles and adapted for use in Fortran by the Pittsburgh Computer Centre, Pittsburgh Pennsylvania, USA.

RESULTS AND DISCUSSION

Correlations and clustering of characters:

Correlations among the 30 characters used in the study were worked out. Highly significant correlations were observed between cartain characters. The character, leaf length, showed high correlation with leaf breadth ($r = 0.896$)*, leaf size index (0.958), petiole length (0.911) and negatively correlated with presence of marginal gall-forming thrips (0.893). Leaf breadth was highly correlated with leaf size index (0.974), petiole length (0.813) and was negatively correlated with thrips infestation (0.849). High negative correlations were also noted between leaf breadth, fruit taste (0.715) and ecological

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*The values given in parenthesis are coefficients of correlation (r).

Table 2

Characters and character states used in the result study

Character Code number	Details of characters and their states
1.	Leaf length in mm
2.	Leaf breadth in mm
3.	Leaf length/leaf breadth
4.	Leaf size index
5.	Petiole length in mm
6.	Spike length in mm
7.	Peduncle length in mm
8.	Leaf length/spike length
9.	Stomatal density per mm^2
10.	Guard cell length in mm
11.	Guard cell breadth in mm
12.	Distance from leaf base to the 2nd pair of ribs
13.	Number of ribs
14.	Leaf shape (1: ovate to ovate-elliptic; 2: cordate; 3: ovate-lanceate; 4: elliptice to elliptic-lanceate)
15.	Leaf base (1: round; 2: cordate; 3: acute to attenuate)
16.	Leaf texture (1: glabrous; 2: sparsely hairy mainly on the veins; 3: hirsute)
17.	Leaf nature (1: membraneous; coriaceous)
18.	Spike shape (1: filiform; **2**: cylindrical; 3: globose)
19.	Spike orientation (1: pendulous; 2: erect)
20.	Spike texture (1: gfsabrous; 2: hirtellous)
21.	Bract type (1: sessile, adnate to rachis; 2: stalked, peltate, orbicular; 3: cupular with decurrent base; 4: fleshy, cup like; 5: oblong, angular and free all around)
22.	Stamen number (1: two; 2: three to four)
23.	Fruit nature (1: free; 2: fused)
24.	Fruit, shape (1: ovate-oblong; 2: spherical; 3: elliptical; 4: ovovate)
25.	Fruit colour change on ripening (1: green to orange and red; 2: green to yellow; 3: green to black)
26.	Fruit taste (1: pungent; 2 : spicy and mildly pungent 3: bitter)
27.	Plant type (1: dioecious; 2: monoecious; 3: predominantly monoecious)
28.	Growth habit (1: shrubby climber; 2: stout woody climber; 3: no climbing habit and trailing on the ground)
29.	Distribution in the natural habitat (1: plains to lower elevations (from 0-500.); 2: plains to higher elevations (from 0-1500 m); 3: lower elevations to higher elevations (from 500-1500 m); 4: found only at high elevations (above 1500 m).
30.	Presence of marginal gall forming strips (1: present; (2: absent)

distribution (0.730). Leaf size index was correlated with petiole length (0.875), thrips infestation (0.909), distance from leaf base to the 2nd pair of ribs (0.790), plant type (0.755) and negatively correlated with fruit taste (0.768). Spike shape was correlated with leaf length/spike length ratio (0.875). Fruit shape and peduncle length was negatively

correlated (0.788), so also fruit colour change and petiole length (0.768). Fruit taste was negatively correlated with leaf width (0.715), leaf size index (0.768) and distance from leaf base to the second pair of ribs (0.782). Plant type had high correlation with leaf length (0.750), leaf size index (0.755) and petiole length (0.780). Fruit shape was correlated with

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spike orientation (0.803). Fruit colour change on ripening was negatively correlated with many of the characters.

The average linkage clustering of characters based on charactar correlations led to the identification of the following character clusters (Fig. 1).
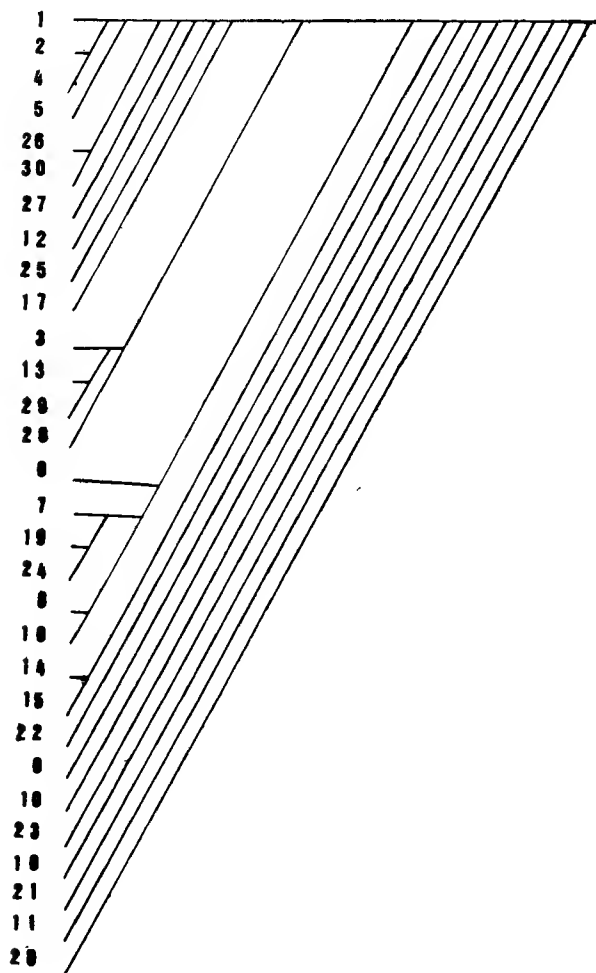
1. Leaf length, leaf breadth, leaf size index.

2. Fruit taste, presence of gall forming thrips.

3. Leaf length / leaf breadth ratio, number of ribs on the leaf, ecological distribution and growth habit.

4. Spike length, peduncle length, spike orientation and fruit shape.

5. Leaf length/spike length ratio and spike shape.

6. Leaf shape and leaf base.

Twelve characters remained unlinked and they were randomly distributed among the taxa.

Clustering of taxa:

The results of the centroid cluster analysis is given in Table 3 and in the dendrogram (Fig. 2). This analysis led to the recognition of six distinct clusters.

The first cluster consisted of the closely related species *P. argyrophyllum* and *P. attenuatum.* Hooker (1886) included them under the Section *Eupiper.* In a D² analysis, employing five characters, *P. attenuatum* and *P. argyrophyllum* were shown to cluster with *P. hookeri;* Rahiman (1985). But in the present study *P. hookeri* (syn. *P. hymenophyllum*) formed an independent cluster. Ecologically also *P. hookeri* differs from the other two, as its distribution is limited to higher elevations.

P. galeatum, P. trichostachyon and *P. schmidtii* formed the second

Fig. 1. Diagram showing the process of character clustering in South Indian *Piper*

Table 3

OTU Clusters and Their Constituent Taxa

Cluster		Taxa
A	-	P. attenuatum, P. argyrophyllum.
B	-	P. schmidtii, P. galeatum,
		P. trichostachyon
C	-	P. nigrum, P. wightii
D	-	P hymenophyllum
E	-	P. silentvalieynsis, P. mullesua
F	-	P. longum

cluster. The first two are closely related and treated accordingly by both Hooker (1886) and Gamble (1925). *P. schmidtii*, though distinct, shares certain morphological character with the other two. Rahiman (1985) obtained a grouping of *P. galeatum*, *P. trichostachyon* and *P. mullesua* in his D² analysis. This is a very unlikely combination because *P. mullesua* is very distinct from the others in several respects. This may be due to the use of too few characters for the analysis by

Rahiman. Hooker included the above three species in two different sections., i. e. *P. galeatum* and *P. trichostachyon* in Sect *Muldera* and *P. schmidtii* in Sect *Psudochavica*. The present results indicate that these three species are closely related. *P. schmidtii* differs from the other two mainly in the nature of the bracts only. *P. idtiischm* also has thicker leaves and occupies a higher altitudinal niche (>1800m).

All the *P. nigrum* collections, including *P. nigrum* var. *hirtellosum* were in the third cluster and *P. wightii* clustered along with it. Hooker (1886) included *P. nigrum* in the sect. *Eupiper* along with *P. attenuatum*, *P argyrophyllum*, *P. hymenophyllum*, and *P. wightii*. In the present study, *P. nigrum* is found to be distinct from the other species in some characters, both morphological and chemical. *P. nigrum* is the only species
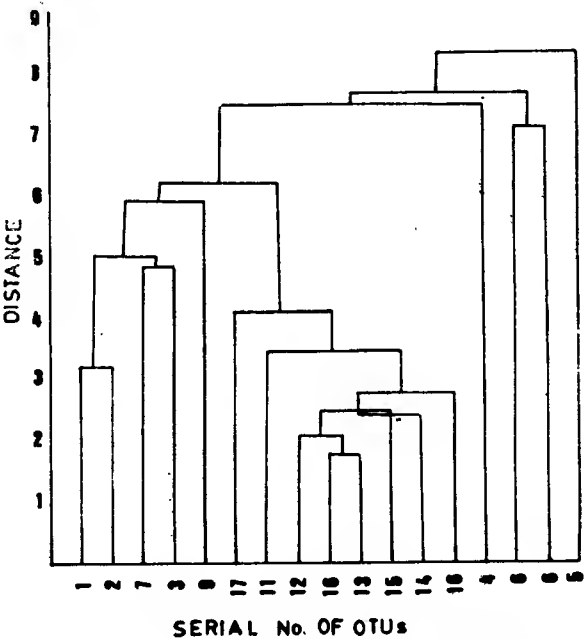

Fig. 2 Clustering of *Piper* spp. by centroid linkage. Dendrogram representing the distances between the taxa studied.

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having the alkaloid piperine and the whole set of terpenoids that contribute to the typical black pepper flavour. *P. wightii* is a species of higher elevations, occurring above 2000 m in certain pockets in Nilgiris. Morphologically this is close to *P. nigrum*, though chemical differences do exist. Their closeness is brought out in this cluster analysis also.

P. hookeri forms the fourth cluster. This species is related to the first cluster in certain respects, but is distinguishable by its prominently hirsute nature. Hooker (1886), Gamble (1925) and Rahiman and Nair (1987) treated this species as related to *P. attenuatum* and *P. argyrophyllum*. This treatment is supported by the present study. Though this forms a separate cluster by virtue of the prominently hirsute nature, the intercluster difference between this and the first cluster is very small and hence the two clusters can be treated as related.

P. silentvalleyensis and *P. mullesua* formed the fifth cluster. The former is a new species described recently by Ravindran. *et al.* (1987) and is unique in having erect, flexuous, filiform spikes, and bisexual flowers. *P. mullesua* is included in the sect. *Chavica* by Hooker (1886). This is a very distinct species,

the only one having globose spikes in south India. In the present study, the relationship between the two are well brought out. They are in fact indistinguishable except for spike characters.

The last cluster consists of a single species, *P. longum*. This species is distinctive by its creeping habit while almost all other south Indian species are climbers. It produces cylindrical spikes with laterally fused fruits and has a distinctive anatomy (Murty, 1985). Hooker has included this species in the Sect. *Chavica* along with *P. mullesua*, but the two differ in several respects. *P. longum* is more closely related to *P. hapnium*, an endangered species, than to *P. mullesua*. Centroid analysis also demonstrates the distinctiveness of *P. longum*, as had already been shown by Rahiman and Bhagavan (1985).

The result of the present study, by and large, vindicate the existing species level classification in the genus. But the prevailing notions about interspecific relationships and consequently, the subgenegric classification, seems to be far from satisfactory. Probably, further studies combining conventional and biosystematic mothods might help in delineating them.

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